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Preliminary Results of Magnetic Field Measurements in the Tail of the Geomagnetic Cavity

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A triaxial flux gate magnetometer was included in the Explorer 14 payload. This instrument was similar to the one carried on Explorer 12 (Cahill and Amazeen, 1963). The range of magnetic field measurement along each axis of the Explorer 14 magnetometer was nominally ±500 gammas. Explorer 14 was launched on 2 October 1962 into an elliptical orbit with apogee near 16 earth radii, inclination 33° and initial angle between the orbit major axis and the earth-sun line 74°. The initial spin rate of the satellite was 9.7 rpm. The satellite also had a precession motion of initial half-angle about 10°, this had decreased to 3° during the period 10-20 October. In November the precession cone opened up to 40° half-angle, decreasing to 2° or less in early January 1963. To date we have analyzed the magnetic data from a number of passes in October and in January when the precession cone was small. The October data are consistent with a geomagnetic cavity boundary, often beyond 16 earth radii, near 90° to the earth-sun line. Similar observations were obtained with Explorer 12 near the same region of the cavity one year earlier; Explorer 12 results indicated that the boundary was often beyond 13 earth radii.

The data obtained in January 1963, when the angle between the major axis of the orbit and earth-sun line was between 140° and 150°, is quite different from that obtained by Explorer 12 and is the basis of the present preliminary report. Some precautionary comments about these data are necessary. There are still some questions not completely answered about 1) the spin axis orientation of the satellite; 2) possible zero level drift and sensitivity changes of the magnetometer. While investigation of these problems is proceeding, this preliminary report is submitted in view of interest expressed by several individuals.

Figure 1 shows measurements obtained on 9 January. This is a period of very low magnetic activity on earth; preliminary K_p indices for 9 January do not rise above 1^+. Thus this record represents the conditions in the tail of the magnetic cavity during very quiet conditions.

The magnitude of the field is close to that predicted until 10 earth radii. Beyond this it is higher than predicted and continues between 30 to 50 gammas out to apogee at 16 earth radii. On this particular pass the field appears to reach a minimum near 12 earth radii and to increase to 40-50 gammas beyond 14 earth radii. This is not a typical feature on other records in this period; it may be a time fluctuation in the magnitude of the field. Also at 10 earth radii the direction of the field commences to depart from that of a dipole field. The most apparent change occurs in the space craft direction angle ψ. The record of ψ becomes more irregular beyond 10 earth radii in addition to the slow change in the average value from about 300° at 10 earth radii to 180° at 14 earth radii. After a gap in the record near 15 earth radii the field is seen to continue similar in direction and magnitude. The angle α deviates from that expected for the earth's dipole field but by a less important amount.

Figure 2 shows a similar record two days earlier. Here the magnitude of the field becomes higher than expected at about 8 earth radii and the change in angle ψ commences there. Deviation in the angle α is also more apparent in this record. The direction angles α and ψ are somewhat different between 5 and 8 earth radii than in Figure 1, presumably because the geomagnetic latitude is different. The negative departure of the field below 8 earth radii may or may not be significant. Further discussion of this feature will be reserved until a more complete assessment of the data has been made. Also apparent in this record is the observation that the field assumes an approximately constant average direction and magnitude beyond 11 earth radii. The same feature was suggested in the 9 January record but beyond 14 earth radii. In the 7 January record the magnitude of the field is somewhat higher than on 9 January, remaining above 50 gammas to 14 earth radii then decreasing slowly to 40 gammas.

Interpretation

These two records, and a few other partial records now available during this period, allow some preliminary statements to be made about the nature of the tail of the magnetic cavity. The magnetic field remains essentially that of a centered dipole, with minor distortions, out to a distance of 8 to 10 earth radii. This distance apparently varies from day to day. Beyond this distance the field remains at a level of 30 to 60 gammas with relatively small short term (period less than one hour) fluctuations in magnitude. Slow time variations may be present with changes of 20-30 gammas occurring in periods of several hours although these cannot be distinguished from spatial variations along the satellite orbit. The direction of the field changes from the dipole direction at 6-10 earth radii to a direction, identified in spacecraft coordinates, as $\psi = 180^\circ$, $\alpha = 140^\circ$ within a transition distance of 2 to 4 earth radii. It appears that when the transition starts at a closer distance as on 7 January the changes occur more rapidly. Once the field direction has reached the values mentioned above the average direction and magnitude remain quite constant out to apogee beyond 16 earth radii.

These results are to be compared with those obtained by Explorer 10, also launched into the tail of the magnetic cavity (Heppner, et al, 1963). Explorer 10 encountered a departure from dipole field direction that occurred gradually between 5 and 10 earth radii. Beyond 10 earth radii the field direction remained relatively constant until the abrupt change beyond 22 earth radii that has been interpreted as first penetration of the cavity boundary. The Explorer 10 trajectory traversed the tail of the cavity considerably south of the geomagnetic equator, apparently close to the edge of the cavity, and near the 2100 local time meridian.

The Explorer 14 satellite passes being discussed, are contained within local time meridians 2300 and 0300. The satellite orbit inclination was 33° and the period under discussion was 2-3 weeks after winter solstice. The satellite was close to the geomagnetic equator during these passes but below the ecliptic plane. Considering theoretical models of the geomagnetic cavity when the earth's dipole is not perpendicular to the earth-sun line, the measurements were perhaps taken near the lower edge of the cavity.

The Explorer 14 measurements are consistent with those of Explorer 10 and indicate a cavity field in the tail stretched away from the sun and from the earth.

The departures from dipole field occurring as low as 7-8 earth radii in January 1963 are to be compared to the SUI charged particle measurements in early December 1962 on the same satellite (Frank, et al, 1963). At that time, also magnetically quiet, the flux of trapped electrons of energies $\rightarrow$40 Kev. showed an abrupt ($-$1000 Km.) decrease near 35,000 Km. (5 earth radii). This decrease closely resembled the abrupt decreases in trapped electon flux seen in Explorer 12 data (Rosser, et al, 1962). These decreases were coincident with penetration of the geomagnetic boundary as observed in the magnetic measurements from Explorer 12 and were observed on the sunlit side of the earth. Trapped electron and magnetic field measurements from Explorer 14 are not yet available on the same pass and we can only point out that the distortion of the magnetic field observed in January occurs at a somewhat greater distance than the trapped radiation boundary observed in December. The abruptness of the decrease in trapped particles is certainly not similar to the slow changes in field direction. These occur in a distance of 10,000 to 20,000 Km. Since the abrupt particle cutoff does not appear to be related to an abrupt change in the local magnetic field, it may be that the cutoff is caused by some large scale characteristic of magnetosphere. The recent work of Hones (1963) may provide an explanation of this cutoff.

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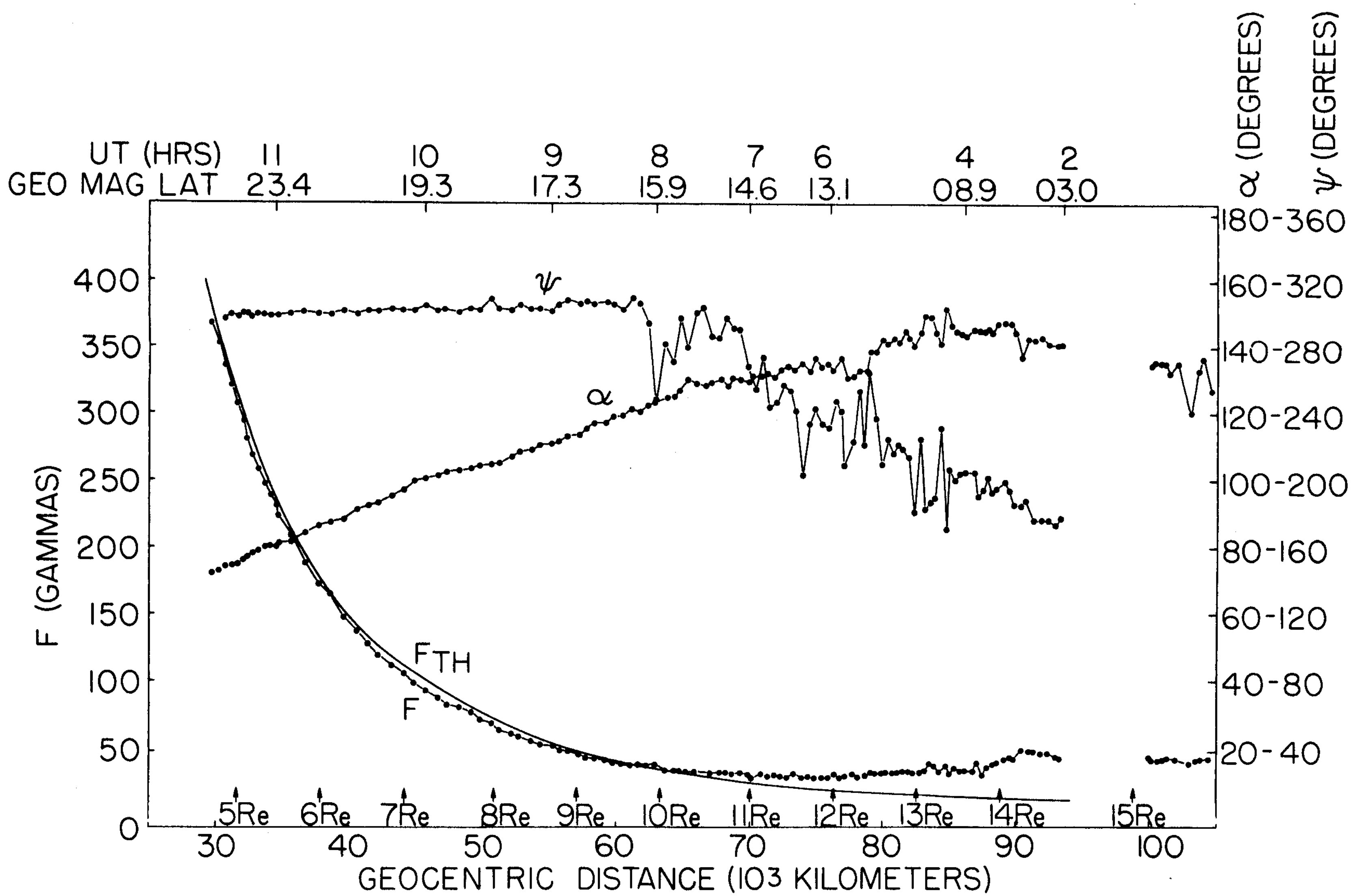
FIGURE CAPTIONS

Figure 1 The magnetometer record for the inbound pass of 9 January 1963 measured magnitude of the earth's magnetic field and the field direction in spacecraft direction angles α and ψ. The points plotted are 16 measurement averages where the measurements are taken 3 times a second.

Figure 2 The record for the inbound pass of 7 January 1963.



UT (HRS)
GEO MAG LAT
11 10 9 8 7 6 4 2
23.4 19.3 17.3 15.9 14.6 13.1 08.9 03.0
α (DEGREES)
ψ (DEGREES)
180-360
160-320
140-280
120-240
100-200
80-160
60-120
40-80
20-40
F (GAMMAS)
400
350
300
250
200
150
100
50
0
ψ
α
F_{TH}
F
5Re 6Re 7Re 8Re 9Re 10Re 11Re 12Re 13Re 14Re 15Re
30 40 50 60 70 80 90 100
GEOCENTRIC DISTANCE (10^3 KILOMETERS)

Figure 1

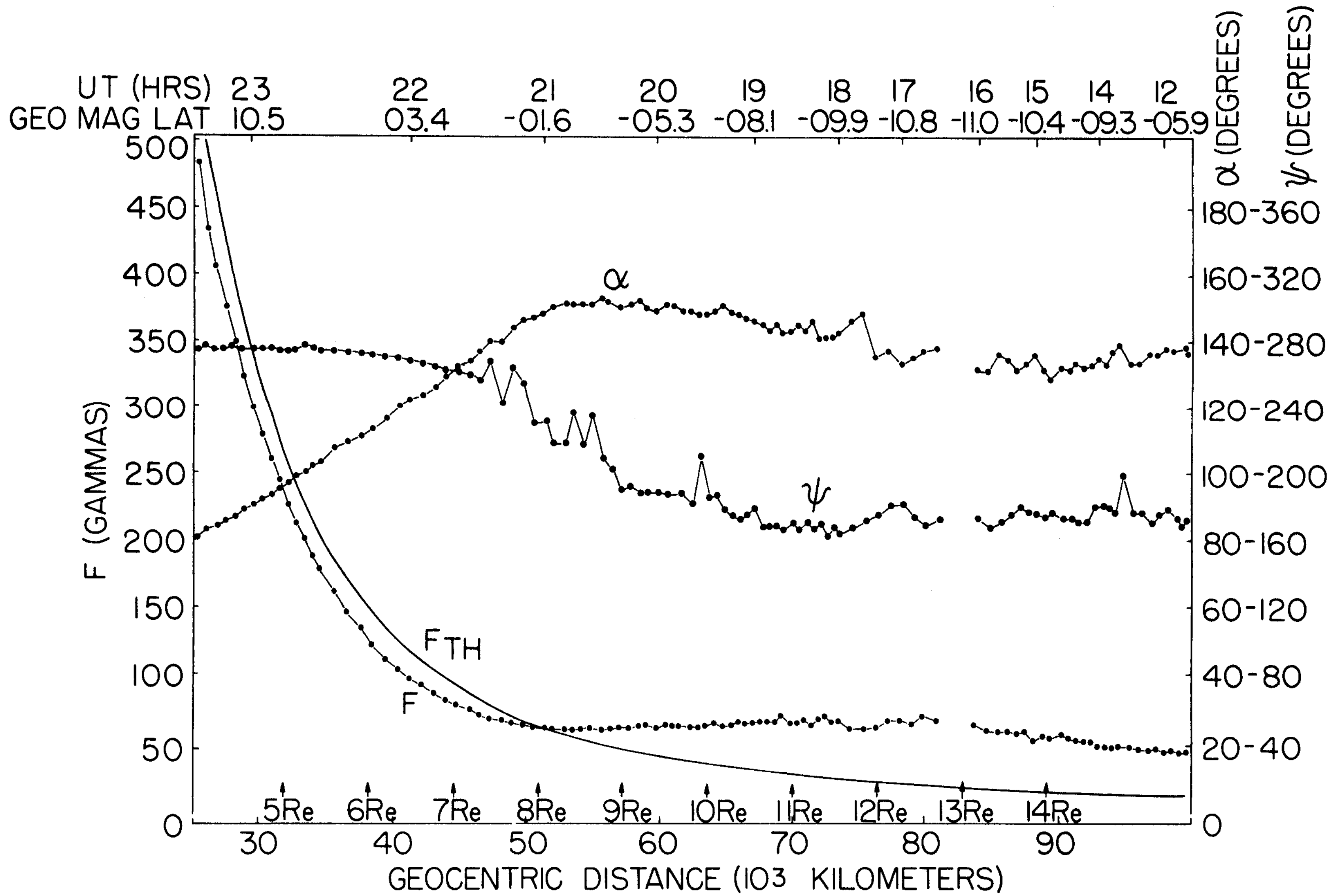

UT (HRS)
GEO MAG LAT
23 22 21 20 19 18 17 16 15 14 12
10.5 03.4 -01.6 -05.3 -08.1 -09.9 -10.8 -11.0 -10.4 -09.3 -05.9
F (GAMMAS)
500 450 400 350 300 250 200 150 100 50 0
α (DEGREES)
ψ (DEGREES)
180-360 160-320 140-280 120-240 100-200 80-160 60-120 40-80 20-40 0
α
ψ
F_{TH}
F
5Re 6Re 7Re 8Re 9Re 10Re 11Re 12Re 13Re 14Re
30 40 50 60 70 80 90
GEOCENTRIC DISTANCE (103 KILOMETERS)

Figure 2